

Description

FLUID DYNAMIC BEARING APPARATUS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to a spindle motor or fluid dynamic bearing apparatus utilized in a recording disk drive such as a hard disk drive (HDD), for example.

DESCRIPTION OF THE PRIOR ART

[0002] A spindle motor or fluid dynamic bearing apparatus is assembled within a hard disk drive (HDD), for example. The fluid dynamic bearing apparatus includes a rotation shaft and a sleeve supporting the rotation shaft. Fluid such as oil is filled between the rotation shaft and the sleeve. The rotation axis of the rotation shaft is aligned with the central axis of the sleeve when the rotation shaft rotates. Dynamic pressure generated in the fluid serves to keep a constant space between the outer peripheral surface of the rotation shaft and the inner cylindrical surface of the sleeve.

[0003] When the rotation shaft stands still, the rotation shaft cannot receive the dynamic pressure from the fluid. The rotation shaft thus inclines. The outer peripheral surface of the rotation shaft contacts the inner cylindrical surface of the sleeve at least partly. When the rotation shaft starts rotating, the outer peripheral surface of the rotation shaft slides over the inner cylindrical surface of the sleeve. This causes abrasion of the rotation shaft and/or the sleeve. Fine dusts are thus generated. The dusts serve to increase the viscosity of the fluid. The increased viscosity of the fluid hinders the rotation shaft from reaching a predetermined rotation speed. Moreover, the dusts may get stuck between the rotation shaft and the sleeve, so that the rotation shaft hardly rotates.

SUMMARY OF THE INVENTION

- [0004] It is accordingly an object of the present invention to provide a fluid dynamic bearing apparatus capable of keeping the rotation of the rotation shaft in a desired condition.
- [0005] According to a first aspect of the present invention, there is provided a fluid dynamic bearing apparatus comprising: a rotation shaft; a sleeve supporting the rotation shaft; fluid filled between the rotation shaft and the sleeve; and a dust catcher disposed between the rotation shaft and

the sleeve.

- [0006] The fluid dynamic bearing apparatus allows the fluid to flow within a space between the rotation shaft and the sleeve during the rotation of the rotation shaft. The dust catcher catches fine dusts within the fluid. The diffusion of the fine dusts can thus be prevented in the fluid. The viscosity of the fluid cannot increase. The rotation shaft keeps smoothly rotating in an expected manner.
- [0007] The dust catcher may be fixed to the sleeve. The fluid is allowed to flow along the surface of the sleeve during the rotation of the rotation shaft. Accordingly, a relative movement can reliably be established between the dust catcher and the fluid. The dust catcher thus efficiently catches the fine dusts. The dust catcher may be made of a synthetic resin. Through holes may be defined in the dust catcher. The through holes serve to catch the fine dusts within the fluid.
- [0008] According to a second aspect of the present invention, there is provided a fluid dynamic bearing apparatus comprising: a rotation shaft; a sleeve supporting the rotation shaft, a groove being defined on an inner surface of the sleeve; fluid filled between the rotation shaft and the sleeve; and a plate member attached to an inlet of the

groove, wherein through holes are defined in the plate member.

- [0009] An inner space can be defined between the bottom of the groove and the plate member in the fluid dynamic bearing apparatus. The fluid flows into the inner space through the through holes defined in the plate member. The fluid passes through the through hole during the rotation of the rotation shaft. Fine dusts in the fluid can be trapped in the through holes. The viscosity of the fluid cannot increase in the same manner as described above. The rotation shaft keeps smoothly rotating in an expected manner. It should be noted that the plate member may be integral to the sleeve.
- [0010] According to a third aspect of the present invention, there is provided a fluid dynamic bearing apparatus comprising: a rotation shaft; a sleeve supporting the rotation shaft; fluid filled between the rotation shaft and the sleeve; and a corrosive added into the fluid.
- [0011] The dusts in the fluid is often made of a metallic material such as brass, stainless steel, or the like in the fluid dynamic bearing apparatus. The corrosive serves to dissolve the metallic material. An increase of the dusts can thus be suppressed or avoided in the fluid. The corrosive may in-

clude a corrosive oil, an oxidative additive, and the like.

[0012] According to a fourth aspect of the present invention, there is provided a fluid dynamic bearing apparatus comprising: a rotation shaft; a sleeve supporting the rotation shaft, an inner surface of the sleeve being opposed to an outer surface of the rotation shaft; fluid filled between the rotation shaft and the sleeve; grooves defined on the inner surface of the sleeve so as to generate dynamic pressure in the fluid; and depressions defined on the inner surface of the sleeve.

[0013] The fluid is introduced into the depressions during the rotation of the rotation shaft in the fluid dynamic bearing apparatus. Fine dusts in the fluid are forced to stay in the depressions. The diffusion of the fine dusts can thus be prevented in the fluid. The viscosity of the fluid cannot increase. The rotation shaft keeps smoothly rotating in an expected manner. In this case, the depressions may be located within the grooves. The fluid is forced to flow along the grooves during the rotation of the rotation shaft. As described above, the fine dusts in the fluid is thus caught in the depressions.

[0014] According to a fifth aspect of the present invention, there is provided a fluid dynamic bearing apparatus comprising:

a rotation shaft; a sleeve supporting the rotation shaft; and a prevention member designed to prevent inclination of the rotation shaft that stands still.

- [0015] The protrusion serves to prevent inclination of the rotation shaft when the rotation shaft stands still. The center of gravity can be prevented from shifting in the rotation shaft. When the rotation shaft starts rotating, the contact area can be minimized between the rotation shaft and the sleeve. The rotation shaft and the sleeve are prevented from abrasion. Generation of fine dusts can reliably be suppressed.
- [0016] The prevention member may be a protrusion formed on the sleeve so as to extend toward the rotation shaft. The protrusion may be integral to the sleeve, for example. A predetermined gap or space may be defined between the tip end of the protrusion and the rotation shaft. The gap ensures avoidance of contact between the protrusion and the rotation shaft during the rotation of the rotation shaft.
- [0017] Alternatively, the prevention member may be a protrusion formed on the rotation shaft so as to extend toward the sleeve. The protrusion may be integral to the rotation shaft, for example. A predetermined gap or space may be defined between the tip end of the protrusion and the

sleeve. The gap ensures avoidance of contact between the protrusion and the sleeve during the rotation of the rotation shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0018] The above and other objects, features and advantages of the present invention will become apparent from the following description of the preferred embodiments in conjunction with the accompanying drawings, wherein:
- [0019] Fig. 1 is a plan view schematically illustrating the structure of a hard disk drive (HDD) as a specific example of a recording disk drive;
- [0020] Fig. 2 is an enlarged sectional view of a spindle motor according to a specific example of the present invention;
- [0021] Fig. 3 is an enlarged partial sectional view of a spindle motor according to a modified example of the present invention;
- [0022] Fig. 4 is an enlarged partial sectional view of a spindle motor according to another example of the present invention;
- [0023] Fig. 5 is an enlarged partial sectional view of a spindle motor according to a further example of the present invention;
- [0024] Fig. 6 is an enlarged view illustrating grooves formed on

the inner surface of a sleeve according to a modified example of the present invention;

[0025] Fig. 7 is an enlarged partial sectional view of a spindle motor according to a still further example of the present invention; and

[0026] Fig. 8 is an enlarged partial sectional view of a spindle motor according to a still further example of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Fig. 1 schematically illustrates the inner structure of a hard disk drive (HDD) 11 as an example of a magnetic recording medium drive or storage device. The HDD 11 includes a box-shaped main enclosure 12 defining an inner space of a flat parallelepiped, for example. At least one magnetic recording disk 13 is incorporated within the inner space of the main enclosure 12. The magnetic disk 13 is mounted on the driving shaft of a spindle motor or fluid dynamic bearing apparatus 14. The spindle motor 14 is allowed to drive the magnetic recording disk 13 for rotation at a higher revolution speed such as 5,400rpm, 7,200rpm, 10,000rpm, 15,000rpm, or the like, for example. A cover, not shown, is coupled to the main enclosure 12 so as to define the closed inner space between the

main enclosure 12 and the cover itself.

- [0028] A head actuator 15 is also incorporated within the inner space of the main enclosure 12. The head actuator 15 comprises an actuator block 17 coupled to a vertical support shaft 16 for relative rotation. Rigid actuator arms 18 are defined in the actuator block 17. The actuator arms 18 are designed to extend in the horizontal direction from the vertical support shaft 16. The actuator arms 18 are related to the front and back surfaces of the magnetic recording disk 13. The actuator block 17 may be made of aluminum. Molding process may be employed to form the actuator block 17.
- [0029] Head suspensions 19 are fixed to the corresponding tip ends of the actuator arms 18. The individual head suspension 19 extends forward from the tip end of the actuator arm 18. A flying head slider 21 is supported on the front end of the head suspension 19. The flying head sliders 21 are in this manner connected to the actuator block 17. The flying head sliders 21 are opposed to the surfaces of the magnetic recording disk or disks 13.
- [0030] An electromagnetic transducer, not shown, is mounted on the flying head slider 21. The electromagnetic transducer may include a read element and a write element. The read

element may include a giant magnetoresistive (GMR) element or a tunnel-junction magnetoresistive (TMR) element designed to discriminate magnetic bit data on the magnetic recording disk 13 by utilizing variation in the electric resistance of a spin valve film or a tunnel-junction film, for example. The write element may include a thin film magnetic head designed to write magnetic bit data into the magnetic recording disk 13 by utilizing a magnetic field induced at a thin film coil pattern.

- [0031] The head suspension 19 serves to urge the flying head slider 21 toward the surface of the magnetic recording disk 13. When the magnetic recording disk 13 rotates, the flying head slider 21 is allowed to receive airflow generated along the rotating magnetic recording disk 13. The airflow serves to generate a positive pressure or lift on the flying head slider 21. The flying head slider 21 is thus allowed to keep flying above the surface of the magnetic recording disk 13 during the rotation of the magnetic recording disk 13 at a higher stability established by the balance between the urging force of the head suspension 19 and the lift.
- [0032] A power source 22 such as a voice coil motor (VCM) is connected to the actuator block 17. The power source 22

is designed to drive the actuator block 17 for rotation around the support shaft 16. The rotation of the actuator block 17 induces the swinging movement of the actuator arms 18 and the head suspensions 19. When the actuator arm 18 is driven to swing about the support shaft 16 during the flight of the flying head slider 21, the flying head slider 21 is allowed to cross the recording tracks defined on the magnetic recording disk 13 in the radial direction of the magnetic recording disk 13. This radial movement serves to position the flying head slider 21 right above a target recording track on the magnetic recording disk 13. As conventionally known, in the case where two or more magnetic recording disks 13 are incorporated within the inner space of the main enclosure 12, a pair of the actuator arm 18 as well as a pair of the head suspension 19 is disposed between the adjacent magnetic recording disks 13.

- [0033] Concentric recording tracks or cylinders are defined on the surfaces of the magnetic recording disks 13. The center of the individual recording tracks is aligned with the rotation axis of the magnetic recording disk 13. Servo information signals are written into the magnetic recording disk 13 so as to establish the recording tracks. The servo

information signals serve to set the orbit of the flying head slider 21. The electromagnetic transducer on the flying head slider 21 follows the recording track so as to write and read binary information data.

[0034] Fig. 2 illustrates the structure of a fluid dynamic bearing apparatus or spindle motor 14 according to a specific example of the present invention. The spindle motor 14 includes a bracket 23 fixed to the bottom plate of the main enclosure 12. A cylindrical portion 23a is formed on the bracket 23. The cylindrical portion 23 stands upright from the upper surface of the basement of the bracket 23. A sleeve 24 is received in the cylindrical portion 23a. A thrust plate 25 is fitted in a lower opening of the sleeve 24. The thrust plate 25 is designed to tightly close the lower opening of the sleeve 24. The sleeve 24 may be made from a metallic material such as brass, stainless steel, or the like.

[0035] First and second columnar spaces 24a, 24b are defined within the sleeve 24. The second columnar space 24b is formed continuous with the first columnar space 24a. The outer diameter of the second columnar space 24b is set larger than that of the first columnar space 24a. A rotation shaft 26 is received in the first and second columnar

spaces 24a, 24b. The rotation shaft 26 is thus supported in the sleeve 24 in this manner. A thrust flange 27 is fixed to the rotation shaft 26. The upper surface of the thrust plate 25 is opposed to the bottom surface of the thrust flange 27. The thrust flange 27 is contained within the second columnar space 24b. The rotation shaft 26 and the thrust flange 27 may be made from a metallic material such as brass, stainless steel, or the like. Fluid such as oil 28 is filled within a space between the rotation shaft 26 and the sleeve 24, namely, within the first and second columnar spaces 24a, 24b.

- [0036] A filter 32 is disposed in a space between the rotation shaft 26 and the sleeve 24. The filter 32 may be positioned at the boundary between the first and second columnar spaces 24a, 24b, for example. The filter 32 extends annularly around the rotation shaft 26. An adhesive may be utilized to fix the filter 32 to the inner surface of the sleeve 24, for example. A predetermined gap is defined between the rotation shaft 26 and the filter 32. Fine through holes are formed in the filter 32, for example. The filter 32 may be made of synthetic resin material such as polypropylene resin, polyethylene terephthalate resin, or the like. Here, polypropylene resin is utilized to estab-

lish a so-called electret filter. The electret filter is designed to utilize static electricity to catch dusts.

[0037] A spindle hub 33 is fixed to the rotation shaft 26. The rotation shaft 26 is inserted into a tight through bore defined in the spindle hub 33, for example. The rotation shaft 26 is thus tightly fitted into the spindle hub 33. The spindle hub 33 is in this manner connected to the bracket 23 for relative rotation around a rotation axis 34. An inner surface of the spindle hub 33 is opposed to the outer cylindrical surface of the cylindrical portion 23a. A yoke 35 and permanent magnets 36 are fixed to the inner surface of the spindle hub 33. Stators 37 are coupled to the outer surface of the cylindrical portion 23a. The individual stator 37 may comprise a core 37a made of stacked metallic thin plates, and a coil 37b wound around the core 37a. When an electric current is supplied to the coils 37b, the magnetic field generated at the coils 37b serves to induce the rotation of the spindle hub 33 around the rotation axis 34.

[0038] For example, three magnetic recording disks 13 are mounted on the spindle hub 33. A through hole 13a is defined at the center of the individual magnetic recording disk 13 so as to receive the spindle hub 33. An annular

spacer 38 is interposed between the adjacent magnetic recording disks 13 around the spindle hub 33. The annular spacers 38 serve to maintain a predetermined space between the adjacent ones of the magnetic recording disks 13.

[0039] A flange 39 is formed on the spindle hub 33. The flange 39 extends outward from the lower end of the spindle hub 33. The lowest magnetic recording disk 13 is received directly on the flange 39. A clamp 41 is attached to the upper end of the spindle hub 33. Four screws 42 are utilized to fix the clamp 41 to the spindle hub 33, for example. The magnetic recording disks 13 and the annular spacers 36 are held between the clamp 41 and the flange 39 in this manner.

[0040] The oil 28 is allowed to flow along the inner surface of the sleeve 24 during the rotation of the magnetic recording disks 13 or the rotation shaft 26. The oil 28 serves to generate dynamic pressure. The dynamic pressure establishes a predetermined constant gap between the outer surface of the rotation shaft 26 and the inner surface of the sleeve 24. The rotation axis of the rotation shaft 26 thus aligns with the aforementioned rotation axis 34. The rotation shaft 26 along with the magnetic recording disks

13 keeps smoothly rotating in this manner.

- [0041] When the coils 37b stop receiving the electric current, the driving force to the rotation shaft 26 disappears. The rotation shaft 26 along with the magnetic recording disks 13 stops rotating. The oil 28 stops flowing. The dynamic pressure disappears, so that the lower end of the rotation shaft 26 is received on the upper surface of the thrust plate 25. The rotation shaft 26 slightly inclines. The outer surface of the rotation shaft 26 partly contacts the inner surface of the sleeve 24.
- [0042] When an electric current is again supplied to the coils 37b, the coils 37b generate a repulsive force against the permanent magnets 36. The outer surface of the rotation shaft 26 slides on the inner surface of the sleeve 24, since the outer surface of the inclined rotation shaft 26 have contacted the inner surface of the sleeve 24 as mentioned above. The rotation shaft 26 and the sleeve 24 abrade. Fine dusts are generated in the oil 28 based on the abrasion.
- [0043] The oil 28 flows between the first and second columnar spaces 24a, 24b during the rotation of the rotation shaft 26 in the above-described spindle motor 14. The oil 28 penetrates through the fine through holes in the filter 32.

The fine dusts in the oil 28 are caught in the fine through holes in the filter 32. The static electricity of the filter 32 serves to hold the dusts thereon. The diffusion of the dusts can be prevented in the oil 28, so that the viscosity of the oil 28 cannot increase. The rotation shaft 26 along with the magnetic recording disks 13 keeps smoothly rotating in an expected manner.

- [0044] A predetermined amount of corrosive or corrosive oil may be added into the oil 28 in the aforementioned spindle motor 14. The content of the corrosive oil may be set equal to or smaller than 0.1% of the total of the oil 28. Alternatively, an oxidative additive may be added into the oil 28. The fine dusts are generated based on the abrasion of the rotation shaft 26 and/or the sleeve 24. The dusts contain the metallic material such as brass, stainless steel, or the like. The corrosive oil serves to dissolve the metallic material. Accordingly, an increase of dusts can be suppressed or avoided in the oil 28.
- [0045] As shown in Fig. 3, the filter 32 may be fixed to the inner surface of the sleeve 24, for example. In this case, an annular groove 43 is formed on the inner surface of the sleeve 24. The filter 32 is fitted into the groove 43. The exposed surface of the filter 32 can be aligned flush with

the inner surface of the sleeve 24. Like reference numerals are attached to the structure or components identical to those of the aforementioned embodiment.

[0046] As shown in Fig. 4, the filter 32 may comprise a cylindrical plate member 44 attached to the inlet of the groove 43. Fine through holes 45 are defined in the plate member 44. The holes 45 may have a circular cross-section. An inner space 46 is defined between the bottom of the groove 43 and the plate member 44. In this case, the plate member 44 may be formed integral to the sleeve 24. Electric discharge machining may be utilized to form the groove 43 as well as the through holes 45 directly on the sleeve 24, for example. Like reference numerals are attached to the structure or components identical to those of the aforementioned embodiments.

[0047] The oil 28 flows between the first and second columnar spaces 24a, 24b during the rotation of the rotation shaft 26. The oil 28 simultaneously flows between the first columnar space 24a and the inner space 46. The oil 28 penetrates through the through holes 45. Fine dusts in the oil 28 can be caught in the through holes 45. The diffusion of the dusts can thus be prevented in the oil 28, so that the viscosity of the oil 28 cannot increase. The rota-

tion shaft 26 along with the magnetic recording disks 13 keeps smoothly rotating in an expected manner.

- [0048] As shown in Fig. 5, fine depressions or dimples 47 may be formed on the inner surface of the sleeve 24. The dimple 47 may define a columnar space inside, for example. The dimples 47 may be located over the same region as the aforementioned groove 43. Electric discharge machining may be utilized to form the dimples 47 directly on the sleeve 24, for example. Like reference numerals are attached to the structure or components identical to those of the aforementioned embodiments.
- [0049] The oil 28 flows between the first and second columnar spaces 24a, 24b during the rotation of the rotation shaft 26. The oil 28 flows into the dimples 47. Fine dusts in the oil 28 stay in the dimples 47. The diffusion of the dusts can thus be prevented in the oil 28, so that the viscosity of the oil 28 cannot increase. The rotation shaft 26 along with the magnetic recording disks 13 keeps smoothly rotating in an expected manner.
- [0050] As shown in Fig. 6, fine grooves 48 are defined on the inner surface of the sleeve 24. The grooves 48 are annularly arranged. In this case, two annular arrangements of the grooves 48 are established around the rotation axis 34.

The annular arrangements may have a constant width. The individual groove 48 may be contoured by a herringbone shape, for example. The grooves 48 serve to generate dynamic pressure based on the flowage of the oil 28. The aforementioned filter 32, groove 43, plate member 44 and groove 47 can be positioned off the area where the grooves 48 are established.

- [0051] As is apparent from Fig. 6, the dimples 47 may be formed within the grooves 48. In this case, the groove 48 includes an upper and a lower straight section 48a, 48b. The lower straight section 48b intersects the first straight section 48a at an angle. A bent section 48c can be defined to connect the upper and lower straight sections 48a, 48b. The dimple 47 can be located in the bent section 48c on the bottom of the groove 48.
- [0052] The oil 28 flows into the groove 48 from the lower straight section 48b during the rotation of the rotation shaft 26. The oil 28 then passes through the bent section 48c into the upper straight section 48a. The oil 28 flows out of the end of the upper straight section 48a. Fine dusts in the oil 28 stay within the dimples 47. The diffusion of the dusts can thus be prevented in the oil 28, so that the viscosity of the oil 28 cannot increase. The rota-

tion shaft 26 along with the magnetic recording disks 13 keeps smoothly rotating in an expected manner

- [0053] As shown in Fig. 7, a prevention member or protrusion 49 may be formed on the inner surface of the sleeve 24 in the aforementioned spindle motor 14. In this case, the protrusion 49 is located at the upper opening of the sleeve 24, for example. The protrusion 49 extends inward in a horizontal direction from the inner surface of the sleeve 24 toward the rotation shaft 26. The protrusion 49 may have an annular shape around the rotation shaft 26, for example. The protrusion 49 may have a rounded out top. A predetermined gap is defined between the protrusion 49 and the rotation shaft 26. The gap ensures avoidance of contact between the protrusion 49 and the rotation shaft 26 during the rotation of the rotation shaft 26. The protrusion 49 may be integral to the sleeve 24, for example. Like reference numerals are attached to the structure or components identical to those of the aforementioned embodiments.

- [0054] The protrusion 49 allows the top of the protrusion 49 to contact the outer surface of the rotation shaft 26 when the rotation shaft 26 stands still. The inclination of the rotation shaft 26 is suppressed. The center of gravity can be

prevented from shifting in the rotation shaft 26. When the rotation shaft 26 starts rotating, the contact area can be reduced to the utmost between the outer surface of the rotation shaft 26 and the inner surface of the sleeve 24. The rotation shaft 26 and the sleeve 24 can be prevented from abrasion. Generation of dusts can reliably be prevented.

- [0055] As shown in Fig. 8, the aforementioned protrusion 49 may be formed on the outer surface of the rotation shaft 26. A predetermined gap should be defined between the protrusion 49 and the sleeve 24 in the same manner as described above. The gap ensures avoidance of contact between the protrusion 49 and the rotation shaft 26 during the rotation of the rotation shaft 26. The protrusion 49 may be integral to the rotation shaft 26, for example. The protrusion 49 serves to prevent the inclination of the rotation shaft 26 as described above. When the rotation shaft 26 starts rotating, the contact area can be reduced between the rotation shaft 26 and the sleeve 24. The rotation shaft 26 and the sleeve 24 can be prevented from abrasion. Generation of dusts can reliably be suppressed.
- [0056] A spindle motor may employ any combination of the aforementioned filter 32, through holes 45, dimples 47

and protrusion 49. The aforementioned spindle motor 14 may be incorporated in a recording disk drive such as an optical disk drive in addition to the aforementioned hard disk drive.